f-cell 2013

Highly efficient fuel cell – Li-batteries direct hybrid

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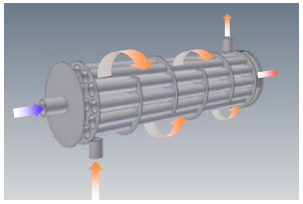
DLR - Institute of Technical Thermodynamics
Electrochemical Systems

Fuel cells systems



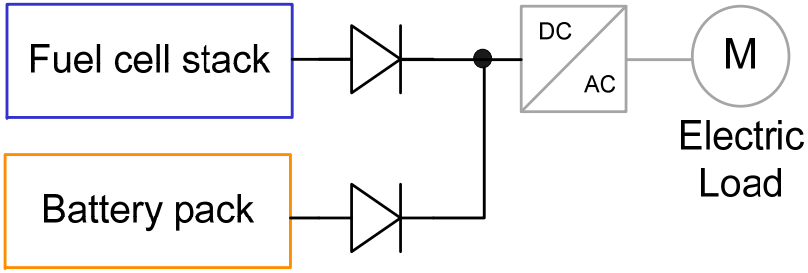
Reformer and stacks

Battery systems

Battery packs

Electrolysis

Hybrid systems



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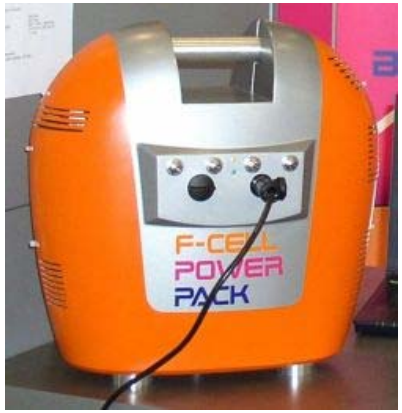
Aircraft application

Antares DLR-H2

Stationary energy supply

Pressurized SOFC

Portable applications



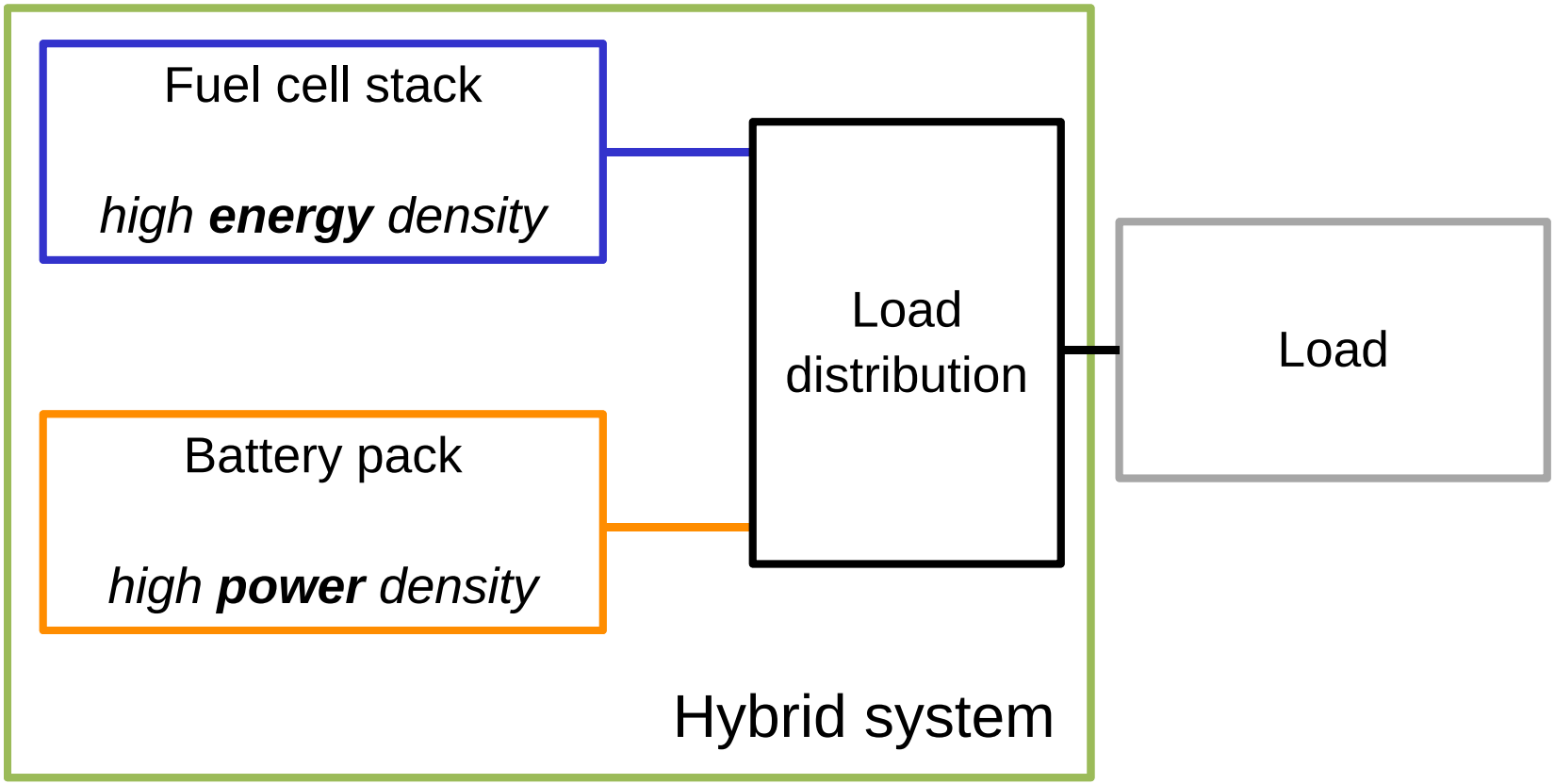
F-Cell Power Pack

DLR

Agenda

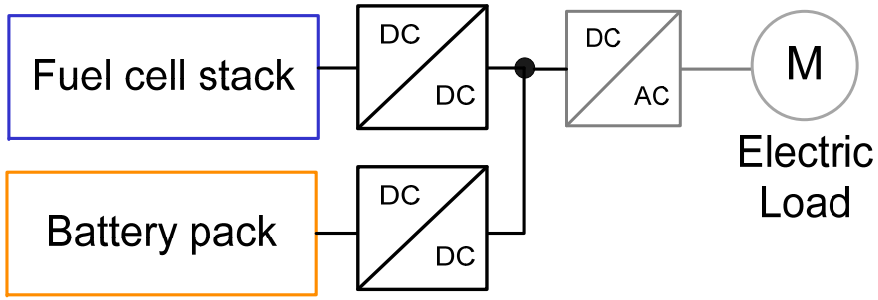
- Concept of an efficient direct hybrid in an aircraft application
    - Battery characteristics and their influence
    - Fuel cell degradation
- Conclusions and outlook

Concept of the direct hybrid



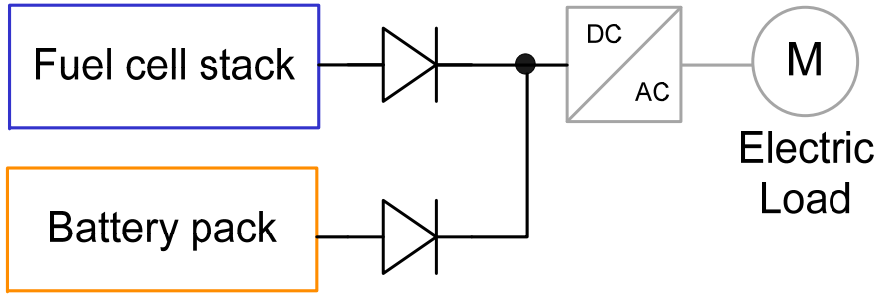
Concept of the direct hybrid

Conventional hybrid systems



- × DC/DC converter for potential separation
- × DC/DC converter are expensive
- × DC/DC converter require cooling system

Direct hybrid system



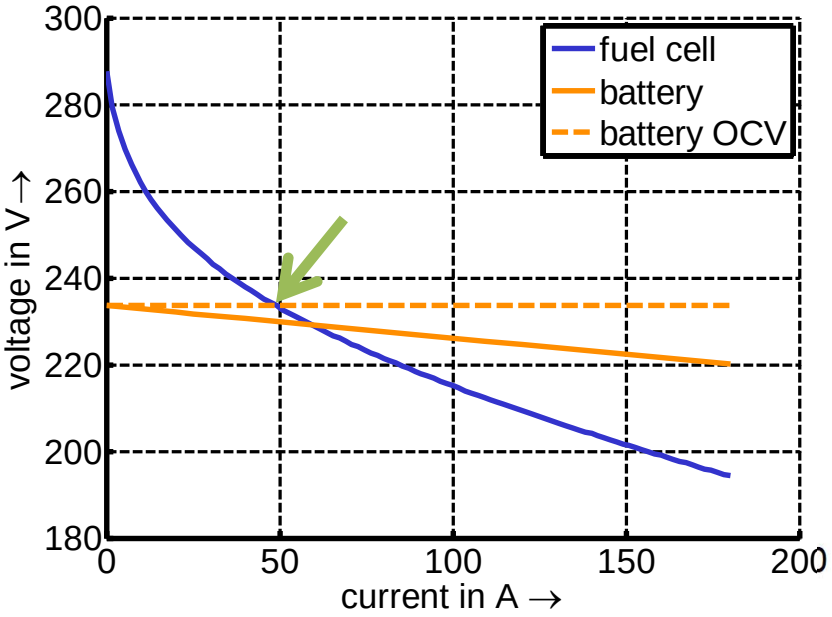
<u>Advantages</u>

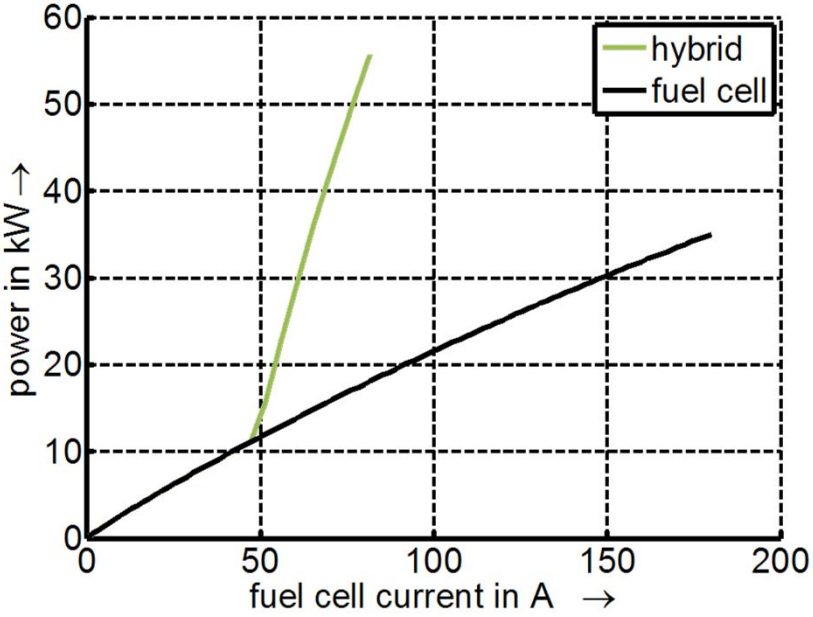
- ✓ No inductance
- ✓ High efficiency
- ✓ Lower cost
- ✓ Light weight
- ✓ Reliable
- ✓ Passive elements

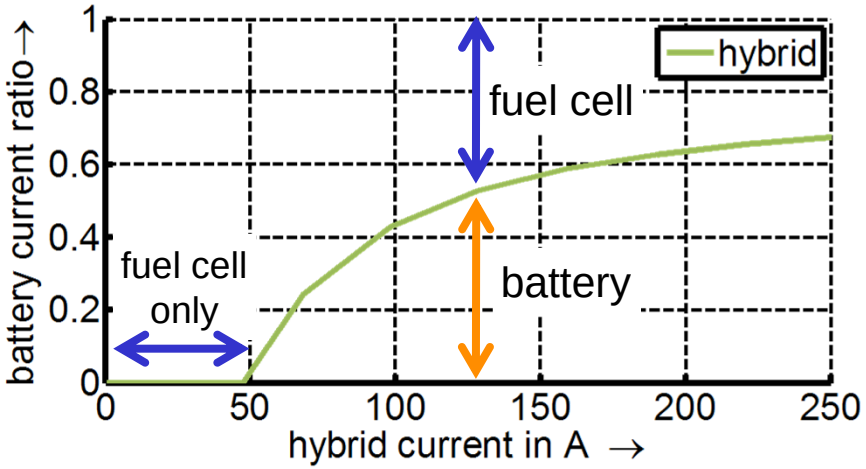
<u>Disadvantages</u>

High voltage spread

Concept of the direct hybrid





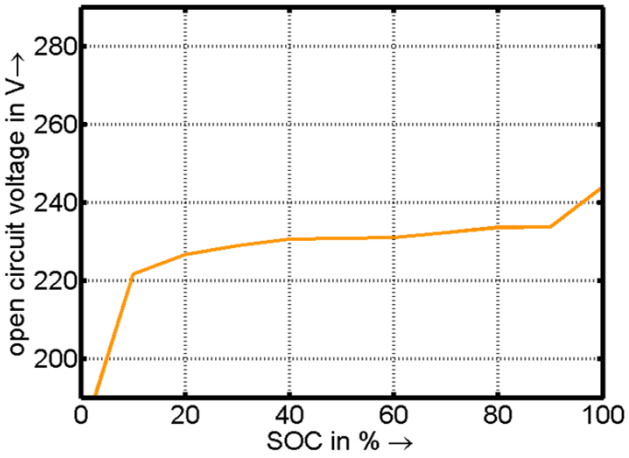


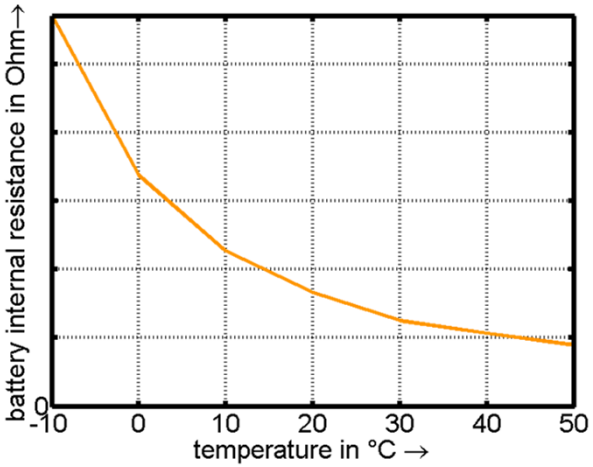
Battery characteristics and their influence

- I-U-characteristics depend on:
  - Fuel cell stack voltage/fuel cell degradation
  - Battery pack voltage: Open Circuit voltage(OCV), State of Charge (SOC)
  - Battery internal resistance

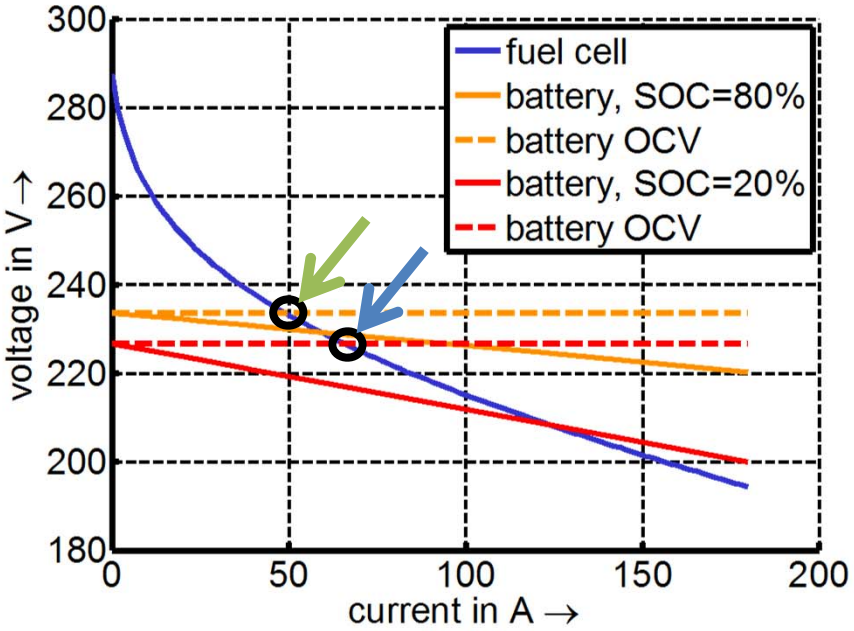
- Two different cell types analyzed
  - Type 1 ($LiFePO_4$, C_{cell}=20 Ah)
  - Type 2 (SAFT VL41M, C_{cell}=41 Ah)

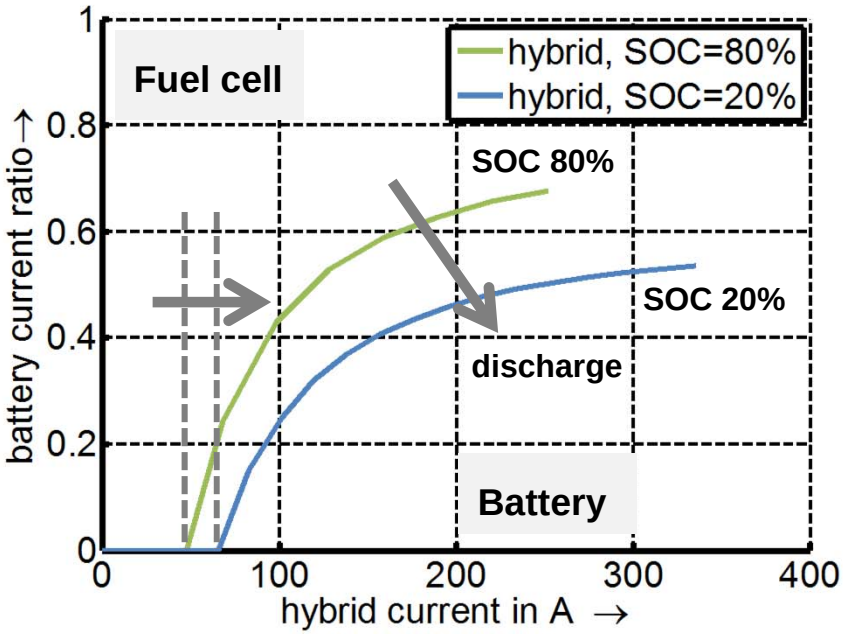
- Both battery packs with approx. same capacitance and OCV by serial and parallel connection of cells





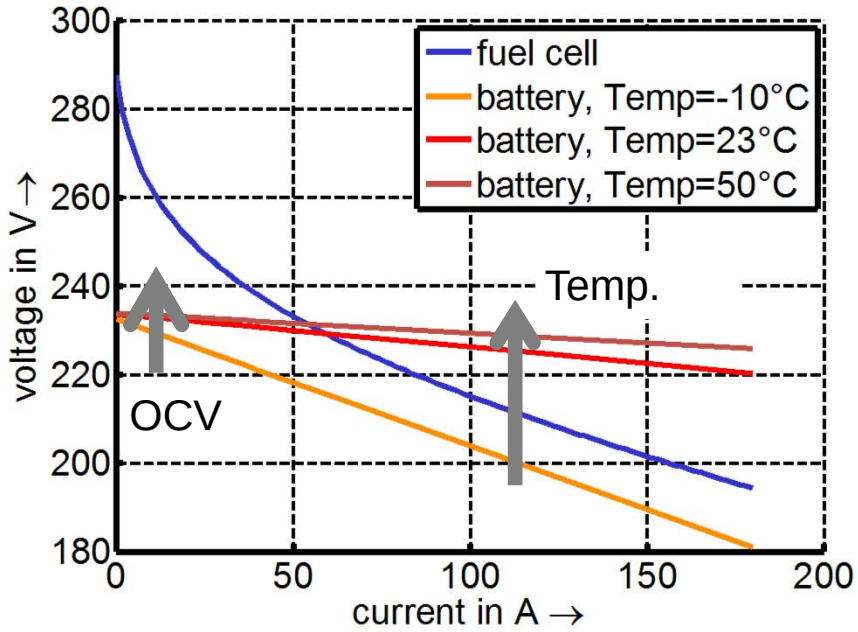
Battery characteristics: State of charge (SOC)

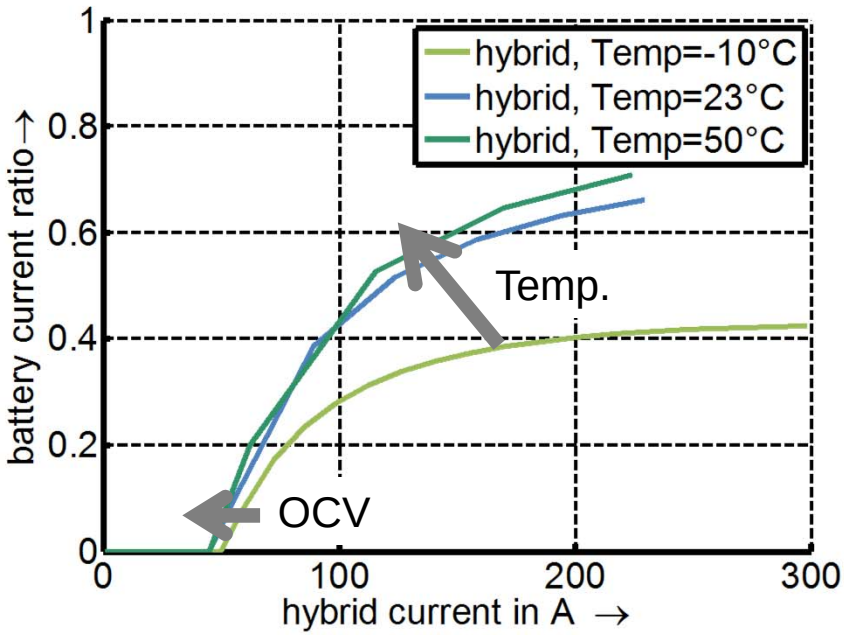




- Battery voltages depend on SOC and current
- I-U-characteristics change while battery is discharged
- Battery current ratio reduces at lower SOC

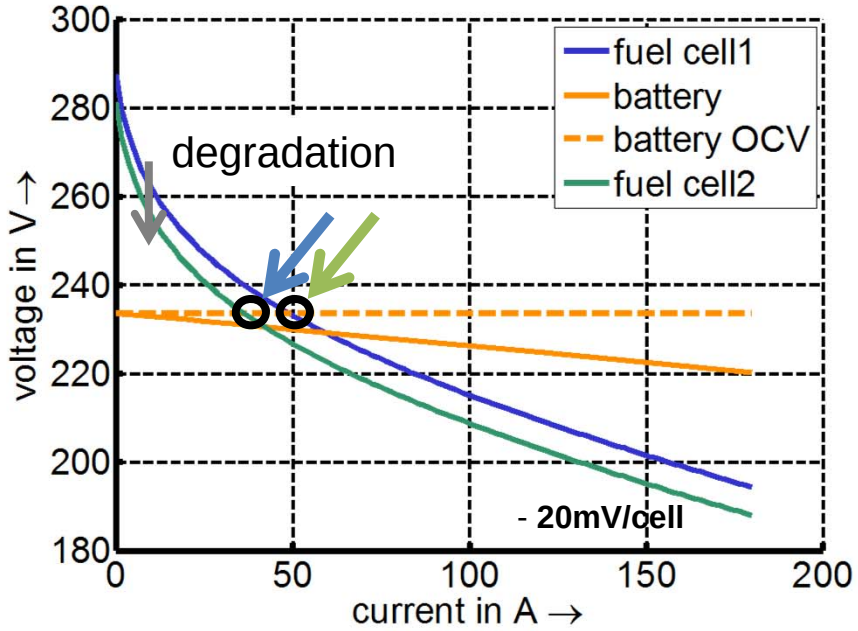
Battery characteristics: Temperature

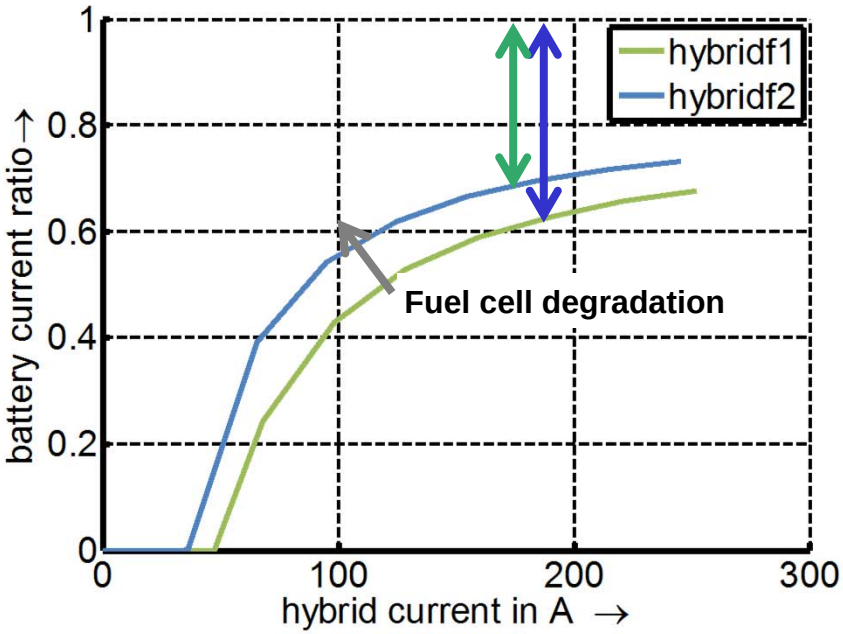




- Battery resistances decreases with higher temperature
- Battery current ratio decreases at lower temperature
- OCV slightly reduces at lower temperature
- Battery heats up over time due to ohmic losses

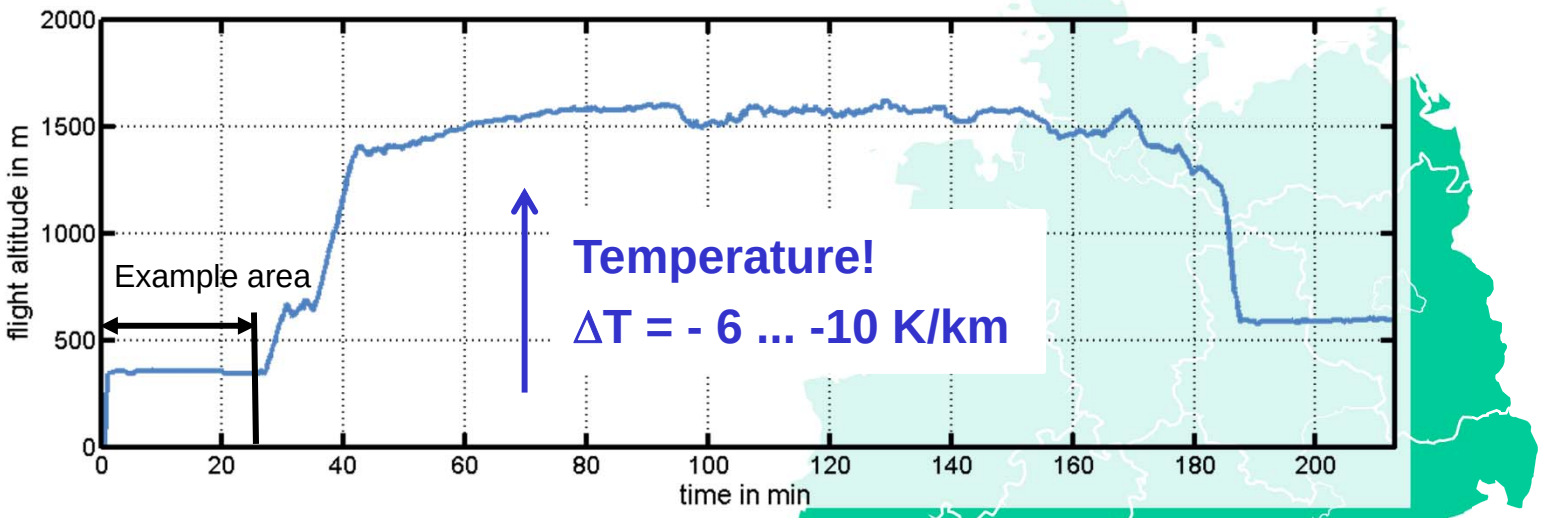
Fuel cell degradation



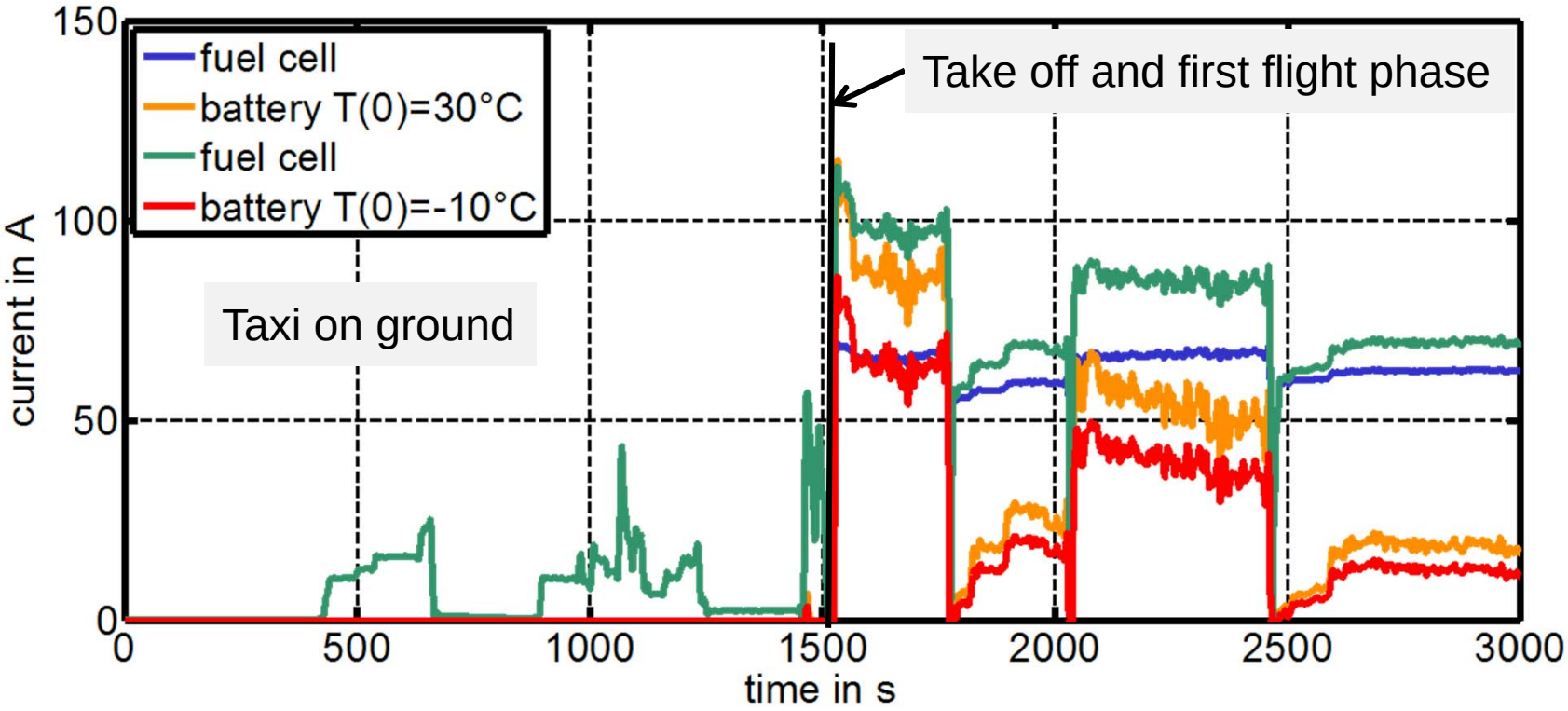


- Fuel cell degrades over time: voltages decreases
- Fuel cell current ratio is reduced over time

Aircraft application: Flight profile

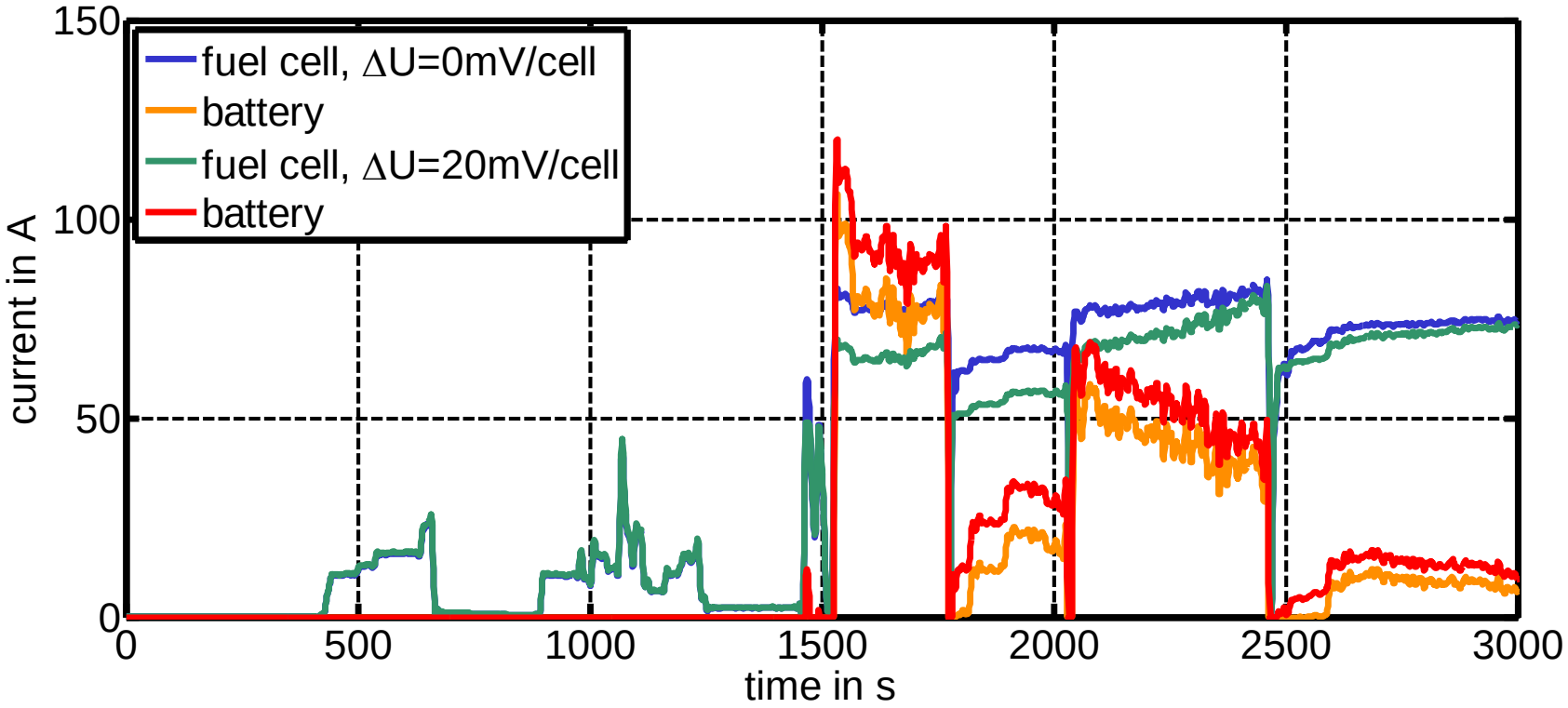


Aircraft application: Battery Temperature



- Hybrid system/battery used only at high power requests until t=3000s
- Different initial battery temperatures
- Higher fuel cell current at lower temperature
- Battery heats up due to ohmic losses – less influence after t=2000s

Aircraft application: Fuel cell degradation



- Comparison between new and degraded fuel cell at room temperature
- Fuel cell current ratio decreases over time

Conclusions and Outlook

- Direct hybrid fuel cell/battery system concept presented
- Hybrid characteristics influenced by
    - Battery state of charge/temperature
    - Fuel cell degradation
- Reliable design for aircraft application
    - Low cost, high efficient, light weight
    - Support fuel cell at high power request (e.g. flight start)
- Very promising results for aircraft application

- **Next step:** Integration and test with Antares DLR-H2
- **Further work:** Efficient dynamic applications

Thank you for your attention!